



Total Maximum Daily Loads (TMDLs): A Perspective

by James L. Martin and Robert H. Kennedy

BACKGROUND

Overview. A recent regulatory program that will provide unique challenges and opportunities for the Corps of Engineers over the next 15 years or more is the Total Maximum Daily Load (TMDL) Program. According to the U.S. Environmental Protection Agency (USEPA 1999b), establishing a TMDL is part of a process whereby impaired or threatened water bodies and the pollutant(s) causing the impairment are systematically identified and a scientifically based strategy—a TMDL—is established to correct the impairment or eliminate the threat and restore the water body.

While the TMDL Program itself as administered by the EPA is relatively recent, the requirement for the program lies in the Clean Water Act (CWA) of 1972. The CWA contained a provision [Section 303(d)] requiring all states to develop and implement TMDLs for their impaired water bodies (those failing to meet water quality standards) and water bodies threatened to become impaired. This requirement has not been aggressively enforced until recently, largely because of the difficulties involved in that enforcement. While in the past regulatory control has focused on individual water bodies and point sources, under the TMDL process all sources (point and non-point) must be considered (USEPA 1991, 1999a, 1999b, 1999f), which poses unique scientific and regulatory challenges. The TMDL process is essentially driving the watershed approach to water quality management (YSI 1999).

Motivation for recent implementation of the TMDL Program has been, in part, the large number of lawsuits compelling EPA to focus on the TMDL provisions of the CWA. The motivation for the lawsuits, and the TMDL Program, is the large number of water bodies that presently do not meet water quality standards. Over recent decades, considerable improvements have been achieved in cleaning up the Nation's waters, primarily through the implementation of point source controls. However, according to the *National Water Quality Inventory* (USEPA 1996), over 40 percent of the Nation's water bodies remain impaired in that they do not meet water quality standards for their designated use. The overwhelming majority of the American people, about 218 million, live within 10 miles of an impaired water body (USEPA 1999g, 1999h). In addition, a large number of water bodies presently meeting standards are threatened in that water quality is declining so that they may soon become impaired.

Based upon the states' recently (1998) compiled lists of impaired waters [the 303(d) lists], approximately 21,000 water bodies have been identified by the states as threatened or impaired. Multiple pollutants impair some of these water bodies, so that potentially over 40,000 TMDLs will be needed over the next 15 years nationwide (USEPA 1999g, 1999h). Water quality issues of concern (in order of frequency of occurrence) include sedimentation, nutrients, pathogens, toxics (organic and inorganic), mercury, and pesticides. Temperature, flow alterations, and other causes of impairment will also be considered.

¹ Also published as ERDC/TN EEDP-01-46.

The TMDL Program does not provide any new regulatory authority for imposing TMDLs. In addition, the TMDL provision of the 1972 CWA provides no additional funding sources for the TMDL Program.

Current Status of Lawsuits. The TMDL Program had been brought to the regulatory forefront in part due to the large number of lawsuits recently filed by environmental groups against the states and the EPA. Most of the lawsuits alleged that states have not complied with the CWA and that EPA had a mandatory duty under Section 303(d) to promulgate TMDLs for impaired water bodies if the states failed to do so. Lawsuits have been filed in virtually every state to date. The status of recent lawsuits can be obtained at <http://www.epa.gov/OWOW/tmdl/lawsuit.html>.

Groups indicating that EPA has exceeded its regulatory authority in attempting to regulate non-point sources have also filed lawsuits. For example, the American Farm Bureau Federation is joining a Yorkville, CA, farm family in a lawsuit that contends the EPA overstepped its authority when it interfered with the family's right to harvest their land by limiting timber harvesting and agricultural activities. (Note that EPA is presently proposing new rules to limit water pollution caused by logging operations by treating silviculture activities as point sources of pollution, which would be regulated under the National Pollutant Discharge Elimination System (USEPA (1999i)).

What's Coming?

EPA is not the only agency being sued over TMDLs. The American Wildlands and the Pacific Rivers Council filed a lawsuit against the U.S. Forest Service charging Lolo National Forest's (MT) Cool Bear Timber Sale violates the Clean Water Act. This is the first suit filed against the Forest Service challenging the provisions of the Clean Water Act dealing with TMDLs.

Pollution lawsuits are emerging as a trend. In addition to lawsuits against EPA, the U.S. Forest Service has been sued over permitting logging operations in areas with impaired water bodies. It is not unexpected that other agencies will be the subject of lawsuits, particularly following the promulgation of TMDLs and their associated implementation plans.

Current Status of TMDL Program. The 1998 listing of impaired water bodies [303(d) lists] required by the CWA has been prepared by most states and approved by EPA and a number of TMDLs have either been completed or are under way. However, there are many unresolved issues involving processes for identifying impaired water bodies and developing and implementing TMDLs. The issues include scientific and regulatory issues as well as those involving the human and financial resources required for implementation. The EPA and many states are increasing or reorganizing their staffs to handle TMDL issues or identifying methods to aid in their completion. However, the effort required to develop the present number of TMDLs is, for most states, beyond their capability. The number of impaired or threatened water bodies listed is also expected to grow as new data become available and new standards are implemented, particularly for nutrients and biota (biocriteria). The sheer number of impairments identified requiring TMDLs, and the complexity of their implementation, will pose a considerable challenge over the next 15 years.

It is not necessary to know the cause of impairment for a water body to be listed as impaired (USEPA 1999a, 1999b, 1999f). However, establishing a TMDL implies a known cause-and-effect

relationship. The relationship between cause and effect is often complex, and involves the interaction of point and non-point sources, hydraulics, sediment transport, and water quality. Therefore, an additional challenge will be the development or integration of methods such as mathematical models, to provide a predictive capability to aid in determining TMDLs.

HOW ARE TMDLS ESTABLISHED? The TMDL is really a process as well as an endpoint. The process includes first identifying the water bodies that are impaired, establishing priorities, and then determining and implementing a TMDL that will remove that impairment or threat of impairment.

The TMDL process is predicated on the generally accepted linkage between material loading from the watershed and the water quality response of the receiving water body. As such, TMDLs attempt to limit loads as a means to reduce or reverse adverse water quality responses.

What Is a TMDL? A TMDL (USEPA 1991, 1999b) is an estimate of the maximum amount of a given pollutant that a body of water can assimilate without violating water quality standards. This total load includes pollutants that come from the end of a pipe (point sources), and from stormwater runoff and groundwater flow (non-point sources), as well as a "margin of safety," which provides a "cushion" needed because of uncertainties naturally associated with estimates. A TMDL also may include an allowance for future increases in pollutant loads due to changes in land use, population growth, and the expansion of business activity.

A TMDL can be expressed as

$$\text{TMDL} = \text{LC} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

where **LC** is the loading capacity, or the greatest loading the water body can receive and still meet standards; **WLA** is the waste load allocation, or portion of the load allocated to existing or future point sources; **LA** is the portion of the load allocated to existing and future non-point sources and natural background; and **MOS** is a margin of safety.

What Is the TMDL Process? The first step in the TMDL process is to identify water bodies that are impaired and should have TMDLs. This involves assessing existing water quality information collected by a variety of monitoring techniques. Computer modeling is typically then used to estimate pollutant loadings to the water bodies, and water quality impacts of the pollutant loadings under varying conditions, such as low stream flows. The modeling is used to estimate the maximum load of pollutants that will not exceed water quality standards. Once this maximum pollutant load (TMDL) is defined, it must be allocated between point and non-point sources, accounting for the margin of safety and future growth. The allocation will balance equity and cost considerations, and may involve innovative approaches such as effluent trading between different pollutant sources. The public, affected dischargers, regional agencies, and local governments are involved in the TMDL process. Each of the steps in the process is summarized below. See "Draft Guidance for Water Quality-based Decisions: The TMDL Process, Second Edition" (USEPA 1999b) for more detailed descriptions.

Identifying the site. Once the water body has been identified as impaired or threatened and needing a TMDL, the next step is to identify the name and geographic location of the site. EPA Reach File Version 3 (RF3), a national hydrologic database, forms the basis for linking the 303(d) identification to geographic information (georeferencing water bodies to RF3; USEPA 1999b). Many states also develop and publish GIS coverages/shape files of their threatened and impaired water bodies.

Identifying the problem. The second step is to identify the problem, which will guide the overall TMDL development process. Problem identification is an extension and expansion of the characterization used to determine the identification of the impairment and the subsequent listing of the water body. The identification includes the standard that is being violated and the pollutant(s) or conditions causing that violation (the identification of the problem that must be addressed). For a specific pollutant violating numeric criteria, this part of problem identification may be straightforward. For narrative standards, such as for most sediment-related listings, the problem may be more complex. For example, the problem may be impairment of fish habitat quality caused by the degradation of stream riparian areas, stream aggradation, changes in the distribution of sediment distributions, or other factors. Failure to correctly identify and define the problem at this stage could result in an inappropriate TMDL (USEPA 1999a).

The problem identification phase also includes: (a) a review of available data used to define the problem; (b) identification of the geographic setting; (c) considerations of any temporal effects on the TMDL; (d) identification of sources; (e) consideration of uncertainty and margin of safety issues; and, (f) an initial identification of potential management alternatives. There are no specific guidelines as to the geographic extent of the site, since it is site-specific. TMDLs can be developed for specific stream reaches or for entire watersheds (USEPA 1999b).

Identifying the target. A TMDL is inherently a quantitative analysis. Therefore numeric targets, or endpoints, must be established that equate to attainment of the water quality standard in order to compute a TMDL. For numeric standards, the target may, or may not, be that standard. In many cases, the target may be based on reductions of pollutant mass loads rather than solely on avoidance of exceedences of concentration-based standards. To meet dissolved oxygen numeric standards, the target may be to reduce mass loadings of oxygen-consuming materials to some level that would result in attainment of the dissolved oxygen standard. For stream temperatures affected by the loss of riparian vegetation, the target may be to restore particular portions of the riparian zone since changes in riparian zones can be related to changes in temperature. For narrative standards, the target may be some indicator that can be used to relate the pollutant sources and resulting water quality impact. For the existing narrative criteria for nuisance algae, the target may be nutrient loads.

Targets for narrative habitat standards have often been related to sediments, such as ratios of anthropogenic to natural sediment loads, sediment concentrations, median particle size, and other indicators. In some cases, multiple indicators and associated numeric target values are used to interpret an individual water quality standard (e.g. multiple fish habitat indicators to interpret acceptable sediment levels) or account for seasonal differences in acceptable pollutant levels in a particular water body (USEPA 1999b). Instream targets may sometimes be supplemented with hillslope targets—measures of conditions within the watershed that are directly associated with water bodies meeting their water quality standards for the pollutant(s) of concern. Target identification

includes identifying the target, the target levels, and comparing historical or existing conditions and target conditions for the indicators selected for the TMDL (USEPA 1999a).

Identifying the deviation from the allowable load. The next step in the process is to identify how far off the present load is from the target. This analysis indicates by how much the load would have to be reduced to meet the target and remove the impairment. The analysis would also suggest if the desired target is attainable (USEPA 1999a, 1999b, 1999f).

Source identification and assessment. The next step is to determine the point, non-point, and background sources of pollutants of concern, including the magnitude and location of these sources. The amounts of pollutants (or indicators) entering the receiving water of concern must be estimated or, in some cases, the amount of pollutant that is bioavailable must be estimated based on historic loadings stored in the aquatic environment. Quantified source analysis is necessary in order to determine levels of pollutant reductions necessary. For non-point source assessment, mathematical models are often used to estimate nutrient runoff, erosion, and other loading rates (USEPA 1991, 1999b).

Linking sources and targets. This portion of the TMDL relates to linking sources and targets, and is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL. That is, this step establishes quantifiable cause-and-effect relationships between the target and sources. Those relationships are then used to establish the capacity of the water body to assimilate loads in order to establish the maximum allowable pollutant load to address the site-specific nature of the problem. The loading, or assimilative, capacity reflects the maximum amount of a pollutant that may be delivered to the water body and still achieve water quality standards (USEPA 1999b).

A number of different loading capacity approaches have been approved as part of TMDLs. Typically, predictive water quality models are used to develop linkages between sources and targets. The linkage may also be based upon linkages inferred from a comparison of local reference conditions and those existing in the watershed of concern (USEPA 1999a, 1999b).

ALLOCATING LOADS AND IMPLEMENTING THE TMDL

Determining the TMDL. Once the sources have been identified and linked to the target, the TMDL can be established. The method used to link the source and target is applied to quantitatively determine the allowable load that will achieve the target, resulting in the removal of the impairment. This allowable load is the TMDL. The allowable load must also include a margin of safety, consideration of future growth, and temporal variations.

One additional component of determining the allowable load is that it must address temporal variations (USEPA 1991, 1999b). Therefore, the loading analysis must consider not only what the load will be but when that loading can occur so that water quality criteria will not be violated (or the violations will only occur at some "acceptably" low frequency). The loading must be determined so that water quality standards will be met for a "reasonable worst case scenario," referred to as the **critical condition**. In a traditional waste load allocation for dissolved oxygen, for example, the critical conditions were taken to be a low flow (typically the 7Q10 flow or 7-day

average flow with a recurrence interval of 10 years), and summertime (hot) conditions. However, since a TMDL addresses point and non-point sources, the identification of critical conditions becomes more complex. For example, the timing and frequency of runoff events may largely dictate their water quality impact.

A margin of safety is a required part of the TMDL (USEPA 1991, 1999b) to account for uncertainty in understanding the relationship between pollutant discharges and water quality impacts. An explicit margin of safety can be provided by reserving (not allocating) a portion of the loading capacity. An implicit margin of safety can be provided by making and documenting conservative assumptions in the TMDL analysis.

TMDLs (and thus, load allocations and wasteload allocations) are typically expressed as “**mass per time, toxicity, or other appropriate measure,**” depending on the type of water body and the sources that contribute to impairment. “**Other appropriate measures**” may include an estimate of the percent reduction in discharge of the pollutant causing the problem, which is needed to achieve water quality standards. For example, if the water quality impairment is due to excessive sedimentation from upland conditions, then the allocations may relate to the decrease in amount of erosion from uplands. If the problem is sedimentation related to channel conditions, then the allocations may relate to the decrease in the amount of bank erosion or the increase in stream stability (USEPA 1999a).

Allocating Loads and Effluent Trading. Once the TMDL has been established, the loads would then be allocated between point sources (waste load allocations, WLA), non-point sources (load allocations, LA), and natural background loadings. The TMDL must also include an explicit and/or implicit margin of safety for each pollutant. If no point sources are present or anticipated, WLAs are zero. If no non-point sources are present or anticipated, LAs are zero (USEPA 1999b). In some recent TMDLs for legacy pollutants, such as PCBs, there are no point sources or natural background loads, and all of the LA has been attributed to contaminated sediments. In some cases a portion of the allowable load may be reserved to address the margin of safety requirement, account for sources that do not receive specific allocations, and/or provide for future sources.

There are no specific federal guidelines for establishing how the loads must be allocated among contributing sources. However, EPA recommends a fair distribution of control costs (USEPA 1999a, 1999b, 1999f).

EPA also supports **effluent trading** (USEPA 1999b, 1999d) where a discharger may be requested to, or choose to, mitigate their discharge by reducing the load from another source. This allows, for example, a point source to arrange for control of non-point source discharge(s) in a watershed in lieu of upgrading its own treatment, as long as the TMDL is still achieved. One point source could also control discharge from another point source. Note also that EPA supports new or significantly expanded discharges being permitted to discharge to impaired water bodies provided they offset their discharge by obtaining pollutant load reductions from an existing source(s) of the same pollutant in the water body. An offset is a form of effluent trading.

Implementation and Reasonable Assurances. The EPA now requires that TMDLs include an implementation plan (USEPA 1999b). Formerly, states prepared implementation plans that were

not a formal part of the TMDL document. In new draft rules, EPA now requires implementation plans that include a description of the actions or measures to be taken, time-lines and milestones for activities associated with implementing the TMDL and achieving water quality standards, legal and regulatory controls for the implementation, and reasonable assurances that the implementation will occur. In a water body impaired solely by non-point sources, reasonable assurances are not required for a TMDL to be approved (USEPA 1999a, 1999b, 1999f).

Note that the TMDL Program does not provide for any new implementation authorities. The program requires states to implement the point source component of TMDLs through existing federal programs with enforcement capabilities, e.g., the National Pollutant Discharge Elimination System (NPDES). EPA suggests that non-point source controls required by a TMDL can be implemented through a voluntary approach or some state or local regulations or other authorities (USEPA 1999b).

Follow-up Monitoring and Evaluation. The TMDL should also include a follow-up plan to monitor the effectiveness of the TMDL and provide a basis for reviewing the TMDL elements or control actions. The monitoring plan can also be used to determine if the objective has been achieved, and the impairment removed (USEPA 1999b).

Public Participation Requirements. The CWA provides for any individual or organization potentially impacted by the development and implementation of a TMDL to participate in the procedures. Particularly for difficult or sensitive TMDLs, stakeholder groups are formed that meet periodically during the TMDL process. Stakeholders often contribute to the process by providing expertise and data. These stakeholder meetings are an ideal way for the Corps to become involved and participate in TMDLs.

Who Will Implement the TMDL? States are responsible for completing TMDLs. However, many local agencies, organizations, and groups are completing TMDLs for the states. For example, the U.S. Army Engineer District, Chicago (CELRC), is developing draft TMDLs for the Grand Calumet River for the state of Indiana.¹ EPA reviews and approves TMDLs. If EPA disapproves a TMDL or the state fails to develop a required TMDL, EPA is responsible for establishing the TMDL for the state.

How Are Impaired and Threatened Water Bodies Identified?

What are the 303(d) lists and how are they developed? One of the requirements of Section 303(d) of the CWA is for states to periodically list all of their impaired or threatened water bodies, known as 303(d) lists. The lists are prepared by each state, territory, or authorized tribe and submitted to EPA by October 1 of every even-numbered year (USEPA 1999b). The basis for listing is the presence or threat of impairment. Impaired water bodies are those that do not achieve water quality standards for their designated use. A threatened water body is one that is presently meeting standards for its designated use, but is expected to become impaired by the next listing cycle (USEPA 1999b).

¹ For more information, contact Thomas Fogarty (CELRC), U.S. Army Engineer District, Chicago, 111 North Canal St., Chicago, IL 60606, 312-353-6400, ext. 3100, Thomas.J.Fogarty@1rc02.usace.army.mil.

According to EPA guidance, all water bodies known to be impaired or threatened must be included on the 303(d) list **regardless of the cause or source of the impairment or threat, or whether or not the source, if known, can be controlled.**

What Criteria Are Used for the Listing? The CWA sets national minimum goals for all waters as “fishable and swimmable.” To support this goal, all states have developed narrative and numeric water quality standards. The criteria used to determine impairment are the water applicable quality standards. Specifically, Section 303(d) states that “each state shall identify those waters within its boundaries for which the effluent limitations required by Section 301(b)(1)(A) and Section 301(b)(1)(B) are not stringent enough to implement any water quality standard applicable to such waters.”

Water quality standards for each state, which can be found in their state regulations, are set to protect and enhance surface water quality, protect public health or welfare, protect aquatic resources, and serve the purposes of the CWA and all its amendments. In practice, each state’s water quality standards form the basis for state programs that control the amount of pollutants entering waters from sources such as industrial sites, sewage treatment plants, storm sewers, and runoff from urban and rural areas.

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designated to protect that use. Standards also include provisions for antidegradation (preventing a water body that meets standards from being degraded). Designated uses include activities such as swimming, drinking water supply, oyster propagation and harvest, and other uses. Each state and tribe establishes water quality criteria to protect the designated uses within its boundaries.

Water quality criteria may be general or specific to a particular chemical. General water quality criteria are in narrative form (e.g., “The waters of the state may not be polluted by ... substances ... that are unsightly, ... odorous, ... create a nuisance, or interfere directly or indirectly with water uses”) and apply to all waters. Specific water quality criteria are usually stated in numeric form and establish limits on the acceptable level (e.g., concentration) of a specific pollutant. The states may also establish toxicity, biological, sediment, or physical (e.g. habitat or flow balance) criteria. Specific water quality criteria may differ among waters with different designated uses. For example, the water quality standard for dissolved oxygen may be 5.0 mg/L oxygen for some designated uses and 6.0 for others.

Sediments and nutrients are listed as the two most common causes of impairment in the nation. However, there are presently no well-defined numeric criteria for either of these pollutants. Their identification as a cause of impairment is typically based more on narrative criteria, such as the impacts of sedimentation on designated uses such as irrigation, fishing, recreation, public water supplies, and aquatic life. For example, a decline in fish habitat attributed to sedimentation has been the subject of a number of recent TMDLs. Similarly, increased eutrophication or

See “Protocol for Developing Sediment TMDLs” (USEPA 1999a), and “Protocols for Developing Nutrient TMDLs ” (USEPA 1999f) for more information (available at <http://www.epa.gov/OWOW/tmdl/techsupp.html>)

presence of nuisance algae has resulted in a number of nutrient TMDLs (see USEPA (1998a, 1999f)). This will change when the EPA adapts nutrient criteria. The tentative target date for the final nutrient criteria is 2000 (for more information on the proposed nutrient criteria go to <http://www.epa.gov/ostwater/Rules/nutsi.html>). When the nutrient criteria are implemented, the number of TMDLs that will have to be completed is expected to increase dramatically.

Additional increases in the number of TMDLs may occur once EPA adopts biocriteria. Presently, toxicity testing (such as chemical-specific or whole effluent toxicity, WET, tests) are used to regulate point source discharges. However, assessing the impact of non-point sources is more difficult. A number of states (e.g. Maine, Ohio, North Carolina, and Florida) have adopted biological criteria designed to measure the cumulative biotic responses to stressors, rather than a concentration or level of a chemical, and EPA is in the process of developing national recommended biocriteria. Guidance for bioassessments and the development of biocriteria for lakes and reservoirs is provided in "Lake and Reservoir Bioassessment and Biocriteria" (USEPA 1998c). EPA is also considering future criteria initiatives for excessive sedimentation, flow, and wildlife (USEPA 1998d).

What Kinds of Data Are Required for the Listing? The kind and amount of data required to support a listing can vary, particularly for narrative standards. They can include monitoring of specific pollutants, toxicity testing (of specific pollutants or WET tests), or in some cases observational data. EPA recommends that, wherever possible, monitored data be used as the basis for the listing process (USEPA 1999b). Under Section 305(b) of the CWA, all states are required to monitor and assess the status of all waters and report this to Congress every 2 years. The 305(b) reports have also been used to identify waters for the 303(d) lists, with the distinction that the 303(d) lists identify waters that need TMDLs.

While all states implement monitoring programs, those programs are necessarily limited. The general consensus is that there is a scarcity of data on many water bodies that are suspected to be impaired (YSI 1999).

There are presently no specific recommendations on the amount of data that is sufficient for that listing. EPA has produced a document titled "Interim Final Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process" (USEPA 1994b).

Data other than state's monitoring data can also be used to identify impairments. These include results from modeling studies, and data collected by other agencies and organizations. Data routinely collected by the Corps could provide the states with an additional source of information. The Corps should also be aware of and ensure the accuracy of all data used in the TMDL process with relation to their projects.

How Are Water Bodies Removed from the List? A water body must remain on the list as long as it is impaired or impairment is threatened. However, there are no specifically recommended procedures yet available for removing water bodies.

What Are the Four Parts of the 303(d) List? The 303(d) list is subdivided into four components, or parts, as summarized below (see USEPA (1991, 1999a, 1999b, 1999f)) for more detailed descriptions). The 303(d) list must also include a priority ranking and schedule for completing the TMDLs. The priority ranking considers the relative value and benefit of water bodies, available resources, the severity of the impairment or threatened impairment, especially threats to human health and endangered species, and the designated uses of the water body. A public review of the list is also required prior to its submittal to EPA for approval.

Part 1: Water bodies threatened by a pollutant. This part of the list includes all water bodies impaired or threatened by a specific pollutant. If the water body is impaired and the specific pollutant causing the impairment is not yet identified, then it will also be included under Part 1 (USEPA 1999b). The pollutants most commonly identified as causing impairment include sediment, nutrients, pathogens, toxics (metals/inorganics, organics), and pesticides. EPA also includes dredged material, heat, munitions, and industrial, municipal, and agricultural wastes as pollutants (USEPA 1999b).

Part 2: Water bodies threatened by pollution. This part of the list includes all water bodies impaired or threatened by pollution. Pollution is defined in the CWA as the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water, and, as such, does not refer to a specific pollutant (USEPA 1999b). The most common form of pollution identified as a threat is hydromodification (channelization, dredging, dam construction, upstream impoundments, and flow regulations/modifications such as water withdrawals; USEPA 1999b). Radiation and exotic species are also considered. Note that EPA does not require TMDLs for these water bodies since there is no pollutant for which to establish a TMDL (USEPA 1999b). However, it can be expected that some plan will be required and that other legal or regulatory tools will be used to address impairments caused by pollution. For example, water bodies impaired by physical barriers that control fish passage may be mitigated through use of legal tools such as the 1998 Transportation Equity Act for the 21st century (DeSena 1999).

The reader is referred to a report on the Ohio EPA's web site (http://chagrin.epa.state.oh.us/document_index/305b.html) explaining that the major reason nearly half of the state's streams are not meeting federal Clean Water Act standards is due to habitat modification – and that the major cause of that is hydromodification (mostly due to agricultural or construction practices).

Part 3: Water bodies with established TMDLs. This part includes water bodies where EPA has approved or established a TMDL but where standards have not yet been attained. Such determinations are based on monitoring data collected according to procedures identified in the TMDL. These water bodies must remain on the list until the standard(s) is met.

Part 4: Water bodies requiring no action. This part includes impaired water bodies where measures taken in accordance with other provisions of the CWA (such as implementation of best management practices or BMPs) are expected to remove the impairment by the next listing cycle. If the impairment is not met by then, the water body is moved to Part 1 of the list.

Where Can I Find the 303(d) List for My State(s)? The easiest way to find the 303(d) list for a state is to either contact the state directly or access the EPA's TMDL Web site (<http://www.epa.gov/OWOW/tmdl/index.html>). A United States map allows users to access the 303(d) lists for each state. A state's map, when displayed, allows access to maps of individual watersheds and the associated 303(d) list. Links are also provided to the appropriate state regulatory agency.

What Does It Mean if Your Water Body Is on the 303(d) List? Listing of a water body indicates it has been identified as impaired and that some action will be required to remove that impairment. As indicated above, TMDLs are only required for water bodies on Part 1 of the list. However, a water body on Part 2 of the list has still been identified as impaired. Having the water body on Part 2 of the list does not mean that the impairment does not have to be addressed, only that a TMDL is not the appropriate process. Having a water body on Part 3 or 4 of the list indicates that some action has been taken to remove that impairment. However, the fact that the water body is impaired may impact or restrict further loadings, such as disposal of dredged materials.

Activities or modifications may also be required as part of the implementation plans that are required as part of a TMDL and directly impact Corps projects or activities. The implementation plan may, for example, limit the amount of discharge into a water body, such as in the disposal of dredged materials. It is also not unreasonable to expect that some change in facility or reservoir operations may be included in an implementation plan.

What if a Water Body Is Not Presently on the List? If a water body is not on the list now, it may be in the future. As of now, 40 percent of the nation's waters have been identified as impaired. This figure comes from the *National Water Quality Inventory* (USEPA 1996), which presents states' findings on which waters are meeting or not meeting water quality standards. The 40 percent figure is derived from the number of waters that states have actually assessed. Not all United States waters have been assessed. A number of states are implementing a revolving watershed approach to identifying impairments, where specific watersheds are identified and prioritized for a detailed assessment. A new 303(d) list will be prepared each even-numbered year, with the most recent year being 1998 and a new list to be developed in 2000.

EXAMPLES OF CORPS ACTIVITIES THAT MAY BE AFFECTED BY OR BE THE SUBJECT OF TMDLS

Reservoir Regulation and Hydropower. Corps reservoirs will be the focus of a number of TMDLs, both for in-reservoir and release water quantity and quality. This may occur where the quality of the in-reservoir and water or tailwater does not meet numeric or narrative criteria.

TMDLs provide a unique opportunity for the Corps to be involved in a process whereby controls in the watershed can be developed to improve reservoir quality, such as in controlling an overabundance of algae. For example, TMDLs for nutrients from point and non-point sources have already been established for a number of lakes and reservoirs (see USEPA (1999f)). In most cases, the impairment that was addressed was a violation of a narrative standard for nuisance algae (as they impact the aesthetic value of the water body). TMDLs will be expected on many additional reservoirs, particularly following the release of nutrient standards planned for later this year (2000).

Similarly, the TMDLs will, for the first time, allow relating controls within the watershed to release water quality.

The TMDL process will also provide a unique challenge for the Corps in that current reservoir operations may result in downstream impairments. Although not regulated as point source discharges, reservoir releases have been identified as a cause of impairment in a number of cases and will be the subject of TMDLs. Examples include impairment due to release of waters with low dissolved oxygen and high concentrations of reduced materials, habitat impairment, and impairment due to water temperatures. Challenges may occur, for example, where it is necessary to maintain cold water for downstream fisheries simultaneously with high water quality. Changes in release quantity may also be suggested as an alternative to improve downstream quality such as by increasing flows to increase waste dilution. Changes in operations to improve quality may also conflict with other designated uses.

The Federal Advisory Committee (FAC) in their report on the Total Maximum Daily Load (TMDL) Program (USEPA 1998b) identified large existing dams as an "extremely difficult problem" since they create a physical structure or physical modification that would be impossible or virtually impossible to remove. The committee did not include the operation, maintenance, or potential modifications to large existing dams as an extremely difficult problem. This would suggest that where impairment would occur, modifications in operations and maintenance, and/or structural modifications, are options for addressing the impairment. The Committee's recommendation was that EPA require states to **include waters** impaired wholly or partially by the existence of dams, or their operations, on their 303(d)(Part 1) lists, and proceed on the **assumption that a feasible TMDL can be developed** for impairments. The TMDL should include a (waste) load allocation(s) for the special challenge source, whereupon the implementation plan must lay out specific steps to address this source based on the nature of the problem. In addition, the FAC indicated that **flow alterations** could be considered as a cause of impairment that may be subject to a TMDL. EPA presently indicates that in situations where the impairment is not caused by a pollutant, a TMDL is generally not the appropriate solution to the problem but requires the listing of water bodies impaired by hydromodification on Part 2 of the 303(d) lists. **EPA does not believe that TMDLs should be the solution to problems substantially caused by hydromodification** (Federal Register, Vol. 64, No. 162). This may change if EPA develops criteria for excessive sedimentation, flow and wildlife, as is being considered (USEPA 1998d). However, it may presently be expected that implementation of some plan will be required (such as development of BMPs) to remove the impairment.

Dredged Material Management and Regulations. The Corps dredges and disposes of about 300 million cubic yards of dredged material annually from Congressionally authorized navigation improvement and maintenance projects. In addition, permit applicants (e.g., port authorities, terminal owners, industries, and private individuals) dredge an additional 100 million cubic yards annually from navigation projects (e.g., ports, berths, and marinas). The Corps reviews projects and issues permits for dredging and dredged material disposal in accordance with applicable laws (404/10 permits). Congressionally authorized projects conducted by the Corps do not receive permits but must comply with the same substantive permitting procedures and requirements. While CWA Section 404 guidelines are the primary criteria by which dredging operations are evaluated, the TMDL Program [Section 303(d)] may also impact these operations.

The TMDL Program provides the Corps with several opportunities related to their dredged material management program. The TMDL Program may result in increased demands for recycling of dredged material for "beneficial uses," including habitat restoration. The Corps has cost-sharing authority under Section 204 of the Water Resource and Development Act of 1992 to enter into cooperative projects with non-Federal sponsors using dredged material from new or existing Federal projects to protect, restore, or create aquatic and ecologically related habitats, including wetlands. Many of the beneficial uses of dredged materials are described in "Engineering and Design - Beneficial Uses of Dredged Material" (U.S. Army Corps of Engineers 1987). In addition, the TMDL Program provides mechanisms for relating long-term port planning to broader watershed management, a need specified in 1994 in "The Dredging Process In The United States: An Action Plan for Improvement" (U.S. Environmental Protection Agency 1994a).

The Engineering and Design Manual (EM 1110-2-5026) as well as a number of publications can be obtained at <http://www.wes.army.mil/el/dots/>

The TMDL Program may also provide additional challenges for Corps dredging programs. Many environmental laws, regulations, and Executive Orders presently govern dredged material disposal activities. The Corps presently evaluates proposed discharges of dredged or fill material using the Section 404(b)(1) Guidelines developed by EPA. These guidelines contain substantive environmental criteria that reflect the biological, physical, and chemical health of aquatic ecosystems. However, the TMDL Program may further impact the disposal of dredged materials. A TMDL would be performed on any water body impaired by a pollutant, and dredged material itself is categorized as a pollutant. In addition, dredged material may contain specific pollutants, such as nutrients, and the allowable load to an impaired water body would be determined through the TMDL process.

CWA Section 401 requires that the Corps obtain certification from the state or interstate water control agencies that the proposed discharge will not lead to a violation of water quality standards (waived if the effects are included in an Environmental Impact statement and submitted to Congress prior to project authorization). Interagency Agreements established under Section 404(q) of the CWA allow EPA and the Departments of Commerce and the Interior to request higher level review within the Department of the Army when

For more information on laws and regulations, see <http://www.usace.army.mil/inet/functions/cw/cecwo/reg/>

they disagree with a permit decision that is about to be made by the District engineer. For water bodies that are identified as impaired [on the 303(d) lists], the disposal of additional materials into those water bodies may be restricted either through the state's permit approval process or through EPA's requests for review of proposed disposal projects. Where water bodies have an approved TMDL, the disposal of dredged material may be interpreted as a load to that water body that would be included in the allowable TMDL. Additional safeguards to protect water quality, fish, and wildlife may also be required during dredging and disposal activities.

Channel Maintenance. The United States has 3.5 million miles of rivers. The 1992 National Water Quality Inventory of 642,881 miles of these rivers stated that only 56 percent fully supported multiple uses, including drinking water supply, fish and wildlife habitat, recreation, and agriculture, as well as flood prevention and erosion control. In the remaining 44 percent of stream miles

inventoried, sedimentation and excess nutrients were the most significant causes of degradation. Sediment problems result from soil erosion from watersheds and streambanks. In addition to inland water bodies, many harbors are also listed as impaired.

The Corps maintains navigation channels within many harbors and inland waterways, which may become subjects of TMDLs. Therefore the TMDL Program will provide both opportunities and challenges for Corps channel maintenance programs.

Many current and planned TMDLs will be focused on reducing sediment sources to water bodies, which could directly benefit the maintenance of channels. The TMDL process allows a link between stream aggradation, the filling of channels with sediments, and sediment source controls. The implementation of bank maintenance and the development and maintenance of riparian ecosystems can also be specified as measures to reduce sedimentation and heat loads. For example, effective "shade targets" have been included in several proposed and final TMDLs in Oregon and California.

In the "Total Maximum Daily Load of Polychlorinated Biphenyls for the Susquehanna River" approved by EPA on April 6, 1999, all of the PCB load was attributed to contaminated sediments, but for this case natural attenuation was selected as the appropriate action alternative.

A number of harbors are not presently maintained due to the presence of contaminated sediments, such as the legacy pollutant PCBs. Where impairment results, the TMDL process allows for a linkage between water quality and loads from contaminated sediments. If natural recovery is not expected to remove the impairment within a reasonable time, dredging may be considered as an alternative for reducing the sediment load, which could consequently improve navigation in these harbors.

The TMDL Program also may provide a unique challenge to the Corps in that modifications to channels (such as channelization, loss of meanders, etc.) may be the subject of TMDLs. The Federal Advisory Committee (FAC), in their report on the TMDL Program (USEPA 1998b) noted that TMDLs will need to address, in some cases, human modifications resulting in high flows and freshwater inflows to estuarine areas. Such modifications can cause channel scouring, changes in flow velocity, and other physical and chemical problems leading to adverse effects on aquatic life and water quality standards. The FAC further identified channelization where development is near the bank, extreme stream modifications (e.g., channelization, loss of meander), and operation and management of dams and channels as causes of impairment.

The FAC recommended that EPA require states to include waters impaired wholly or partially by modifications to instream flows on their 303(d)(Part 1) lists. The FAC recommended that states identify strategies to deal with impairments caused wholly or partly by modifications to flow and to include them in TMDL implementation plans. The FAC further recommended that

For more information on stream restoration, see "Stream Corridor Restoration, Principles, Processes and Practices (revised 11/99) at http://www.usda.gov/stream_restoration/newgra.html

federal agencies recognize their responsibility to work within existing legal structures to address flow modification issues that fall under their jurisdiction as part of TMDLs and that EPA should assist and encourage other federal agencies to meet these responsibilities.

It is also noted in EPA's Office of Water's "Guidance for Water Quality-Based Decisions: The TMDL Process" (USEPA 1991,1999b) that in some situations water quality standards — particularly designated uses and biocriteria — can only be attained if nonchemical factors such as hydrology, channel morphology, and habitat are also addressed. EPA states that it is appropriate to use the TMDL process to establish control measures for quantifiable nonchemical parameters that are preventing the attainment of water quality standards. The control measures, in this case, would be developed and implemented to meet a TMDL that addresses these parameters in a manner similar to chemical loads.

Land Management. Release of materials from federal lands and facilities may be considered as a loading source in a TMDL and affects land management and planning. Examples include point sources and non-point source runoff, such as may result from military activities. The Department of Defense (DoD) is the third-largest federal land management department in the United States, with 25 million acres of land to manage on more than 425 major military installations. In addition, the Corps also manages approximately 25 million acres of land associated with civil works projects (approximately 750 water resource projects). Activities at DoD installations and Corps-managed civil works projects, such as training/testing, the maintenance and operation of military vehicles and aircraft, runoff from roads and bridges, stormwater runoff, and sewer overflows are potential sources of non-point source pollution and may potentially impact nearby surface waters. States are responsible for developing TMDLs on federal lands with EPA assistance. Federal land managers must then assure that (waste) load allocations over which they have authority and oversight are met.

Monitoring and Assessment. The Corps maintains an extensive monitoring network within and across Corps projects. The Corps also works cooperatively with or sponsors other agencies to collect data or provides training and equipment for monitoring. The resulting data should prove extremely useful in determining listings or in the planning of TMDLs. The Corps' extensive data collection experience should also prove useful to the states in the collection of new data in support of TMDLs.

Where Can I Get Information and Help?

Who Should I Contact? To determine the status of a water body or listing, the initial step should be to contact the TMDL coordinator within the state(s) in which your project resides. It may also be useful to contact the USEPA State Coordinator in the EPA Region.

Web Sites.

1. EPA's TMDL site (<http://www.epa.gov/OWOW/TMDL/>): This site has information on TMDL case studies, links to all the state and tribal TMDL sites, links to the Watershed Academy (training), links to Non-point Source News Notes, status of 303(d) lists, TMDL lawsuits, and TMDL Technical Advisory Committee Report, and more.

2. EPA's Watershed sites (<http://www.epa.gov/OWOW/Watershed/>): This site has EPA's watershed newsletter, along with links to a number of relevant, helpful, and informative watershed publications, lists of training opportunities, a watershed tools directory, and information on a variety of funding sources for point and non-point pollution programs and more. Important EPA phone numbers are also listed.
3. Surf Your Watershed (<http://www.epa.gov/surf/>): This site has pertinent water quality data on any watershed in the United States.
4. National Service Center for Environmental Publications (<http://www.epa.gov/ncepihom/thanks.html>): This site has over 5,000 environmental documents that can be ordered.
5. National Environmental Publications Internet Site (<http://www.epa.gov/ncepihom/nepishom/>): This site has over 6,000 EPA documents.

References, Manuals and Literature.

- AMSA. (1999). Evaluating TMDLs . . . Protecting the rights of POTWs (available from <http://www.amsa-cleanwater.org/>)
- DeSena, M. 1999. "Regulatory, EPA proposal would clarify definitions of impaired water bodies," *Water Environment and Technology* 11(7), 20-21.
- Environmental Law Institute. (1997). "Enforceable state mechanisms for the control of nonpoint source water pollution," Research Report, Project No. 970300.
- U.S. Army Corps of Engineers. (1987). "Engineering and design - Beneficial uses of dredged material," Engineer Manual 1110-2-5026, Washington, DC.
<http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-5026>
- U.S. Environmental Protection Agency. (1985). "Guidance for state water monitoring and waste load allocation programs," EPA 440/4-85-031.
- U.S. Environmental Protection Agency. (1991). "Guidance for water quality-based decisions: The TMDL process," EPA 440/4-91-001.
- U.S. Environmental Protection Agency. (1993). "Guidance specifying management measures for sources of nonpoint pollution in coastal waters, Chapter 6: Management measures for hydromodification; Channelization and channel modification, dams, and steambank and shoreline erosion," EPA-840-B-93-001c.
- U.S. Environmental Protection Agency. (1994a). "The dredging process in the United States: An action plan for improvement," Report of the Interagency Working Group on the Dredging Process to the Secretary of Transportation (Revised July 15, 1997), Washington, DC.
<http://www.epa.gov/OWOW/oceans/ndt/report.html>
- U.S. Environmental Protection Agency. (1994b). "Interim final guidance for planning for data collection in support of environmental decision making using the data quality objectives process," EPA QA/G-4.

- U.S. Environmental Protection Agency. (1995). "Final water quality guidance for the Great Lakes system." Federal Register, Mar. 23, 1995, Vol. 60(56), 15365-15424.
- U.S. Environmental Protection Agency. (1996). "National water quality inventory: 1996 report to Congress," U.S. Environmental Protection Agency, Office of Water.
- U.S. Environmental Protection Agency. (1997). "Compendium of tools for watershed assessment and TMDL development," EPA 841-B-97-006.
- U.S. Environmental Protection Agency. (1998a). "National strategy for the development of regional nutrient criteria," EPA 822/R-98-002.
- U.S. Environmental Protection Agency. (1998b). "Report of the Federal Advisory Committee on the total maximum daily load (TMDL) program: The National Advisory Council for Environmental Policy and Technology," EPA 100-R-98-006.
- U.S. Environmental Protection Agency. (1998c). "Lake and reservoir bioassessment and biocriteria technical guidance document," EPA 841-B-98-007.
- U.S. Environmental Protection Agency. (1998d). "Water quality criteria and standards plan — Priorities for the future," EPA 822-R-98-003.
- U.S. Environmental Protection Agency. (1999a). "Protocol for developing sediment TMDLs (First Edition)," EPA 841-B-99-004.
- U.S. Environmental Protection Agency. (1999b). "Draft guidance for water quality-based decisions: The TMDL process (Second Edition)," EPA 841-D-99-001.
- U.S. Environmental Protection Agency. (1999c). "Technical guidance manual for developing total maximum daily loads: Book 2, Rivers and streams; Part 1 - Biochemical oxygen demand/dissolved oxygen & nutrient eutrophication," EPA 823/B-97-002.
- U.S. Environmental Protection Agency. (1999d). "Effluent Trading in Watersheds Policy statement," EPA 800-K-96-001.
- U.S. Environmental Protection Agency. (1999e). "The lake and reservoir restoration guidance manual," EPA 440-4-90-006.
- U.S. Environmental Protection Agency. (1999f). "Protocol for developing nutrient TMDLs (First Edition)," EPA-841-B-99-007.
- U.S. Environmental Protection Agency. (1999g). "Total maximum daily load (TMDL) program, talking points," available at <http://www.epa.gov/OWOW/tmdl/tptmdl.html>.
- U.S. Environmental Protection Agency. (1999h). "Total maximum daily load (TMDL) program," EPA841-F-99-003A.
- U.S. Environmental Protection Agency. (1999i). "Proposed regulatory revisions to the total maximum daily load program and associated proposed regulatory revisions to the national pollutant discharge elimination system and the water quality standards programs," EPA 800-F-99-002.
- YSI, Inc. (1999). "Getting Started with TMDLs," by Wesley M. Jarrel, prepared for YSI, Inc. (can be downloaded from www.ysi.com).

List Servers: (note there are presently no list servers specifically for TMDLs)

1. Biological Criteria/Biological Assessment List server
(<http://www.epa.gov/OST/Tools/biocrite.htm>)
2. EPA's Regulatory Alert
(<http://es.epa.gov/oeca/ore/enfalert/>)
3. EPA's Non-Point Source Information List Server
(<http://www.epa.gov/OWOW/NPS/changes.html>)
4. EPA's Standards and Applied Sciences List Server
(<http://www.epa.gov/OST/Tools/sasnews.html>)

Corps Assistance Programs

1. Dredging Operations Technical Support Program (DOTS, contact Mr. Tom Patin, patint@wes.army.mil, <http://www.wes.army.mil/el/dots/dots.html>)
2. Conservation Assistance Program (CAP, contact Mr. Russel Tillman, tilmanr@wes.army.mil, http://www.wes.army.mil/el/cap_pam.html)
3. Wetlands Regulatory Assistance Program (WRAP, contact Dr. Russell Theriot, therior@wes.army.mil)
4. Water Operations Technical Support Program (WOTS, contact Dr. John Barko, barkoj@wes.army.mil)

POINTS OF CONTACT: For additional information, contact the authors, Dr. James L. Martin (601-634-3714, martinj@wes.army.mil) or Dr. Robert H. Kennedy (601-634-3659, kennedr@wes.army.mil) or the Managers of the Water Quality Research Program, Dr. John Barko (601-634-3654, barkoj@wes.army.mil) or Mr. Robert C. Gunkel, Jr., (601-634-3722, gunkelr@wes.army.mil). This technical note should be cited as follows:

Martin, J. L., and Kennedy, R. H. (2000). "Total maximum daily loads (TMDLs): A perspective," *Water Quality Technical Notes Collection* (ERDC WQTN-MI-07), U.S. Army Engineer Research and Development Center, Vicksburg, MS.
www.wes.army.mil/el/elpubs/wqtncont.html

NOTE: *The contents of this technical note are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products.*

APPENDIX A: ACRONYMS AND DEFINITIONS

Antidegradation Preventing a water body that meets standards from being degraded.

Bioassessment Evaluation of the biological condition of a water body.

Biocriteria Numeric values or narrative expressions describing reference biological conditions of aquatic communities inhabiting waters of a given designated aquatic life use.

BMP (Best Management Practices) A practice considered the most effective way to prevent or reduce pollution levels from non-point sources.

CAP Conservation Assistance Program.

CFR Code of Federal Regulations.

Critical Condition A reasonable worst case set of environmental conditions.

CWA (Clean Water Act) Passed by Congress in 1972 to “restore and maintain the chemical, physical and biological integrity of the Nation’s waters.”

Designated use Specific use designated for a water body used in setting standards, such as drinking water, recreation, etc.

DoD Department of Defense.

DOTS Dredging Operations Technical Support Program.

Effluent trading Practice of a point or non-point sources “trading “ their allocation to another source, or reducing loads from another source, so that the overall TMDL is still achieved.

EPA Environmental Protection Agency.

FAC Federal Advisory Committee.

GIS Geographic Information System.

HUC or HUCs Hydrologic unit code or hydrologic unit codes.

Impairment Does not attain water quality standards or, for thermal discharges, does not have or maintain a balanced indigenous population of shellfish, fish, and wildlife.

LA Portion of the load allocated to existing and future nonpoint sources and natural background.

LC Loading capacity, or the greatest loading the water body can receive and still meet standards.

LEDO Long-term Effects of Dredging Operations Program.

LERRD Lands, easements, rights-of-way, relocations, and disposal sites.

MOS Margin of safety.

NPDES National Pollutant Discharge Elimination System.

NPS Non-point source.

Nutrient criteria Regional limits for nutrient concentrations for water bodies having a similar physical nature.

Pollutant Dredged material, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Pollution Man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water.

P&S Plans and specifications.

Reasonable assurance For TMDLs, demonstration that each WLA and LA will be implemented.

Standard (Water Quality) Combination of a designated use for a particular body of water and the water quality criteria designated to protect that use.

Threatened water body A water body that currently attains water quality standards but where data or information indicated that it will not meet those standards by the time the next list is submitted to EPA.

TMDL Total maximum daily load.

WET Whole effluent toxicity tests.

WMP or WMPs Watershed management plan or watershed management plans.

WOTS Water Operations Technical Support Program.

WQLS or WQLSs Water quality limited segment or water quality limited segments.

WLA Waste load allocation, or portion of the load allocated to existing or future point sources.

WRAP Wetlands Regulatory Assistance Program.

WRDA Water Resources Development Act.

WRTC Wetlands Research and Technology Center.

AD NUMBER	DATE	DTIC ACCESSION
1. REPORT IDENTIFYING INFORMATION		20000925 104 REQUE 1. Put you on reve. 2. Complet 3. Attach to mailed 4. Use unc. informa 5. Do not oi for 6 to DTIC: 1. Assign A 2. Return to
A. ORIGINATING AGENCY US Army Engrg Res & Dev Center, WES		
B. REPORT TITLE AND/OR NUMBER ERDC WQTN-MI-07		
C. MONITOR REPORT NUMBER		
D. PREPARED UNDER CONTRACT NUMBER		
2. DISTRIBUTION STATEMENT Approved for public release; Distribution is unlimited.		

DTIC Form 50

PREVIOUS EDITIONS ARE OBSOLETE